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Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

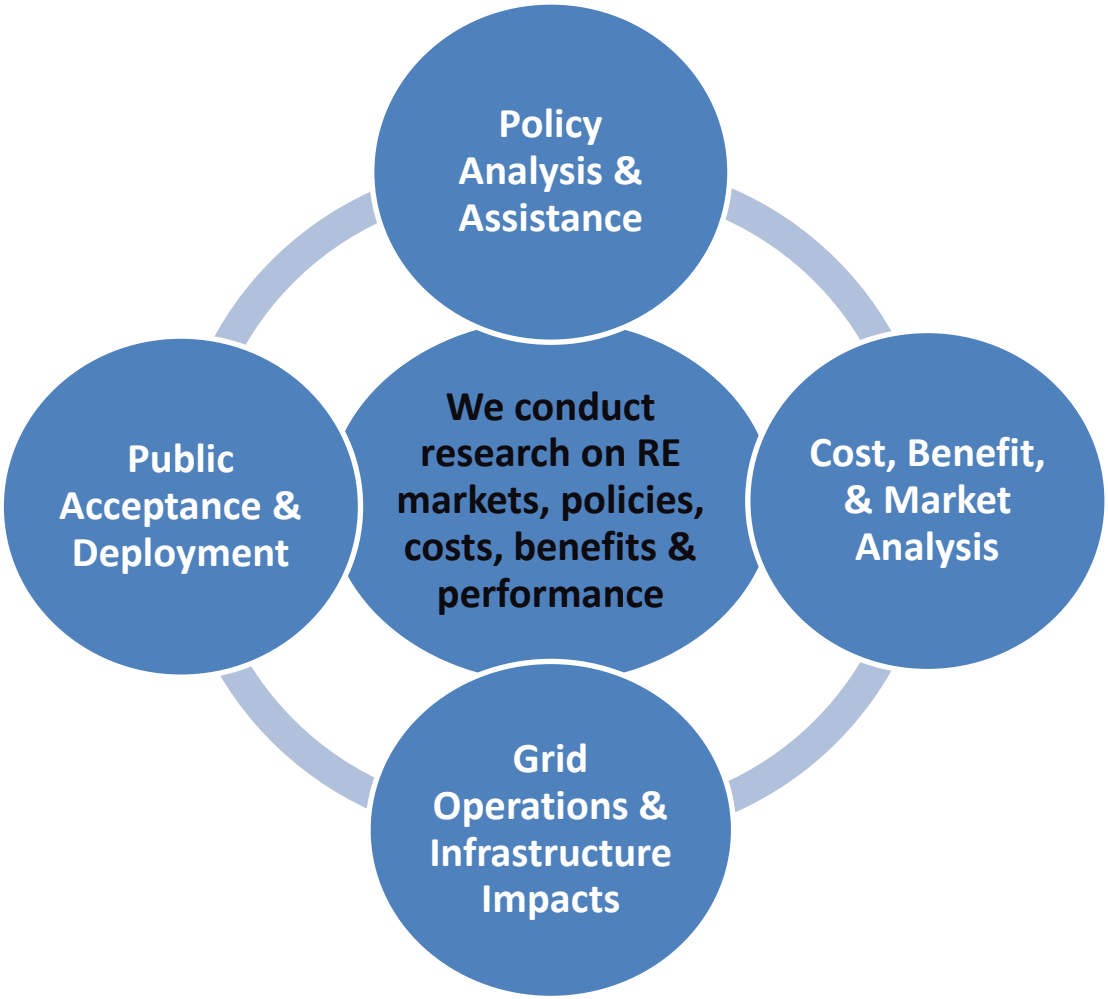
Greening the Grid:
Informing Decision-Makers About the Complexities and Opportunities of Renewable Energy Deployment

Ryan Wiser

Lawrence Berkeley National Laboratory

March 2015

Emphasis of LBNL's Applied Renewable Energy Research



Our work in each of these areas focuses on renewable power, with an emphasis on wind and solar electricity

LBNL STAFF

- Ryan Wiser
- Mark Bolinger
- Galen Barbose
- Ben Hoen
- Andrew Mills
- Naim Darghouth
- Dev Millstein
- Joachim Seel
- Joe Rand
- Use of consultants and collaborators is common

Four Basic Product Types To Inform Decision-Makers

- **Annual Data and Information Reports**
- **Deep Dives into Cost and Performance Trends**
- **Variety of Other Selected Topical Analyses**
- **Direct State and Federal Policy Assistance**

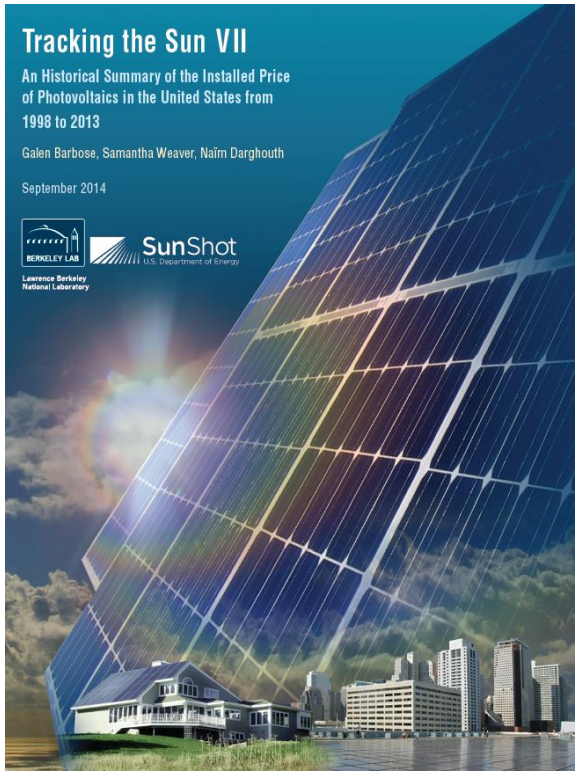
Each type of product, and each individual project, has a different intended use and audience

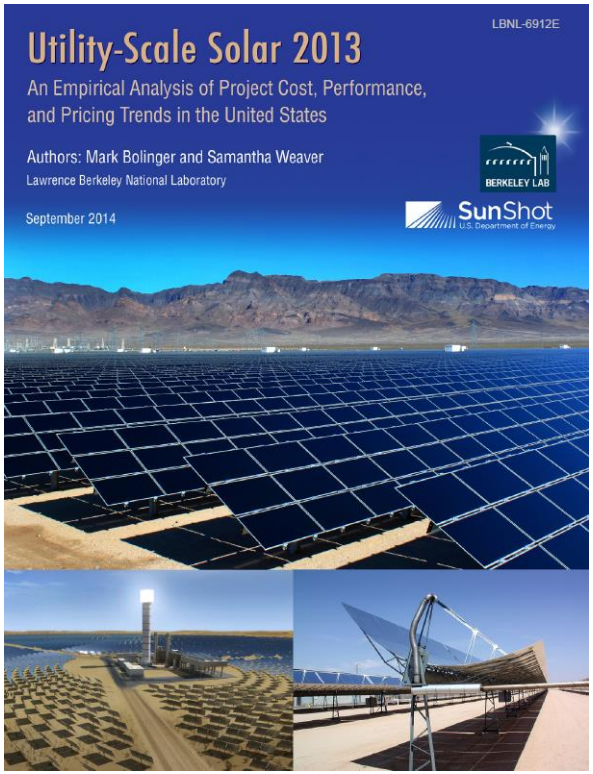
Much of our work, though funded by the DOE, is intended to inform external audiences

Annual Data and Information Reports

Four Annual Reports: Providing Basic Information to Support Decision-Making

Wind Power *Since 2007*	Customer-Sited Solar *Since 2008*	Utility-Scale Solar *Since 2013*



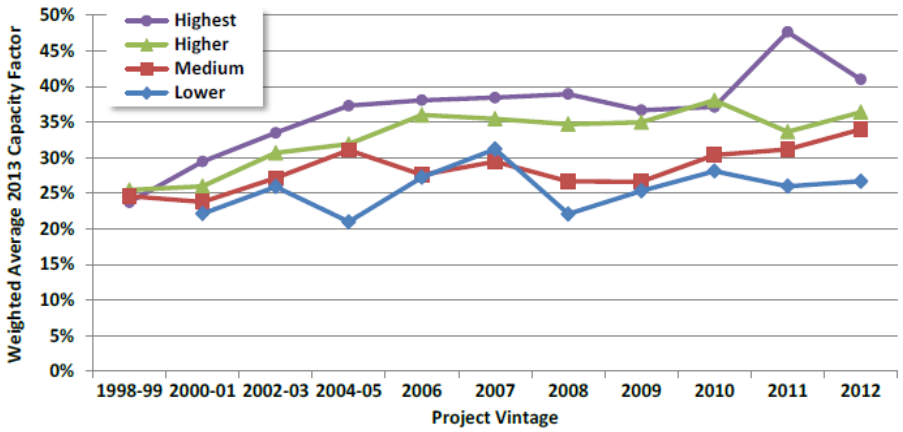


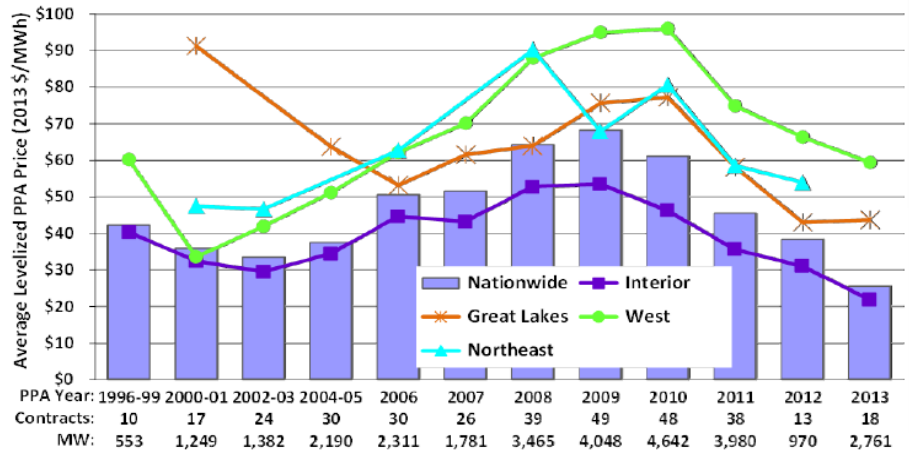
State renewables portfolio standards (RPS): In addition to the three annual reports noted above, LBNL regularly tracks the design and impacts of state RPS policies, with information provided online and through regular presentations

Three Wind and Solar Annual Reports

Scope: core focus is tracking cost, performance, and pricing

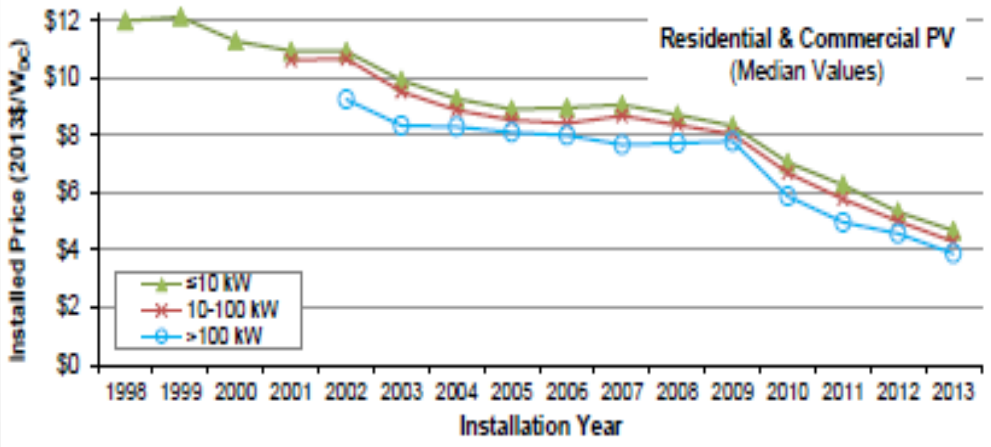
WIND ENERGY

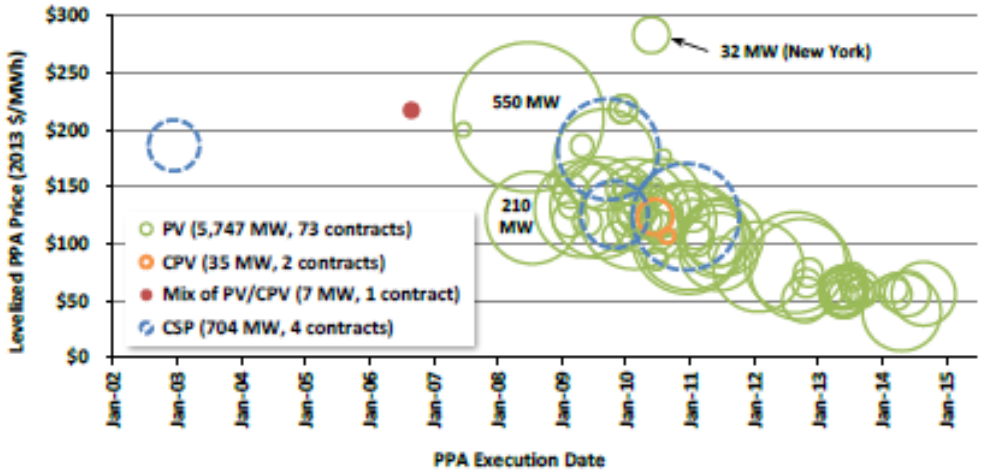




Source: Wiser and Bolinger. LBNL Report. 2014..

SOLAR ENERGY

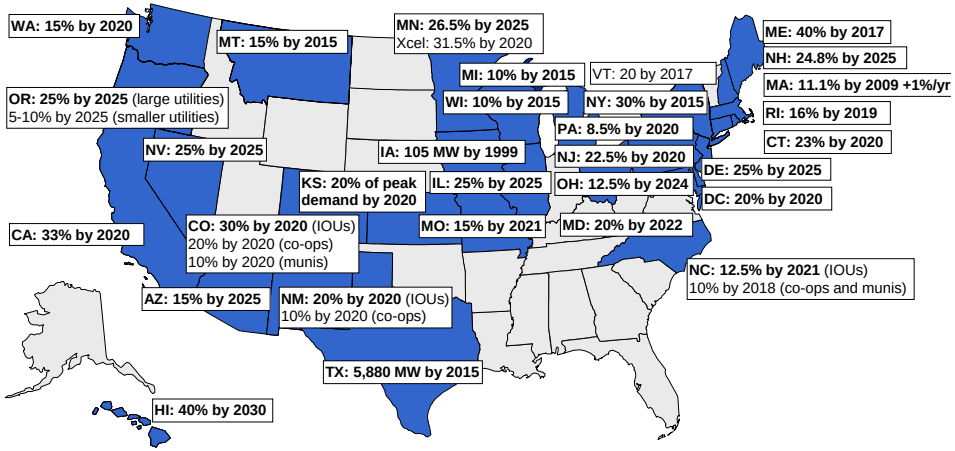


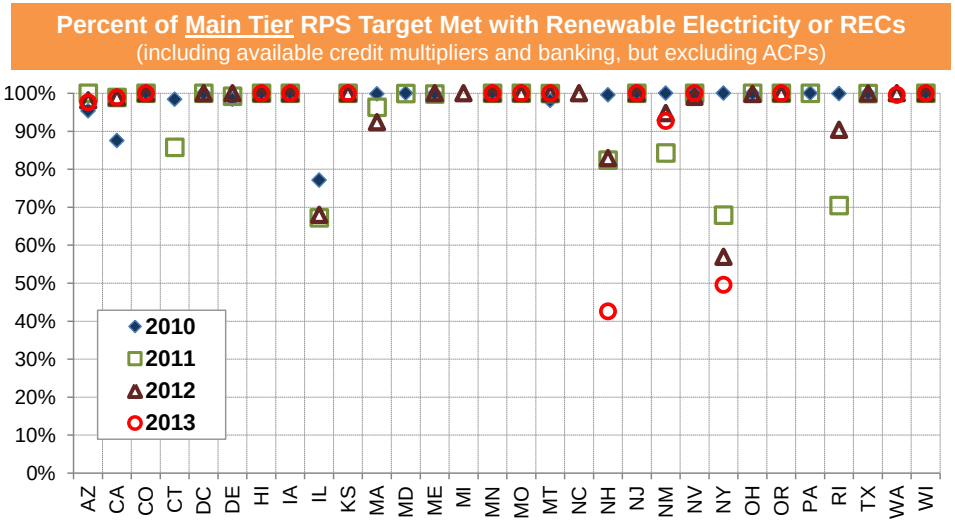


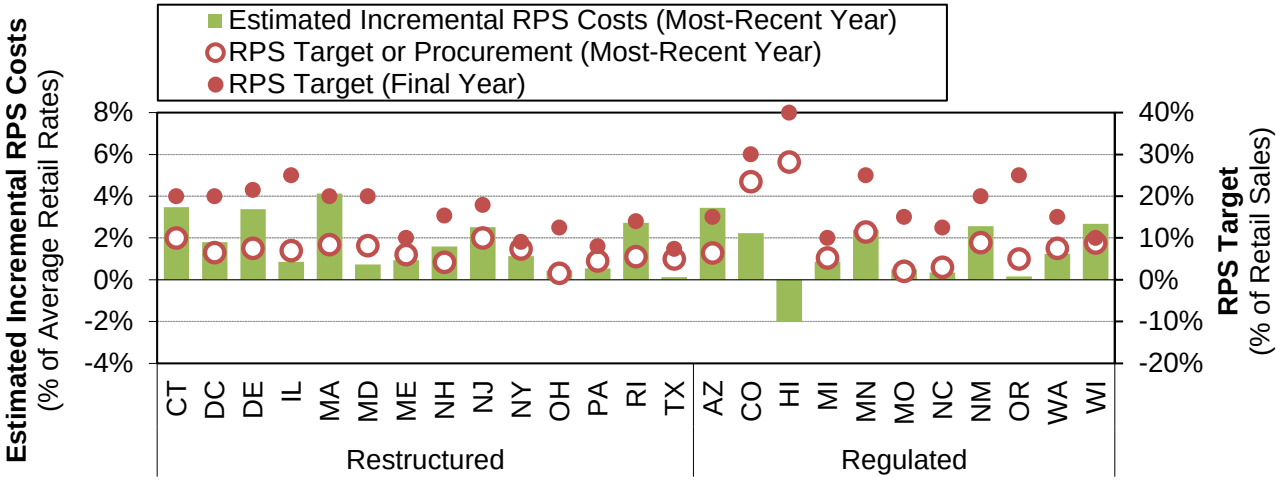
Sources: Barbose, Weaver, Darghouth. LBNL Report. 2014.; Bolinger and Weaver. LBNL Report. 2014.

State Renewables Portfolio Standards

Scope: policy design details, renewable energy demand, compliance results, compliance costs and rate impacts







Sources: Wiser et al. *Energy Policy*. 2011; Heeter et al. LBNL Report. 2014.

Direct Use of Data from Annual Reports: Examples

- Inform DOE R&D cost targets and progress
  - DOE Wind Program
  - DOE Solar Program
- Inform modeling assumptions
  - Wind Vision study
  - Renewable Electricity Futures study
  - EIA Annual Energy Outlook
  - WECC interconnection-wide transmission planning
  - Many, many more…
- Inform policy and market decisions
  - Benchmark for “reasonable” cost for CPUC CSI program
  - Used in utility resource planning, e.g., NPCC Power Plan
  - Utilities, policymakers, RE industry regularly seek and use data

Deep Dives into Cost and Performance Trends

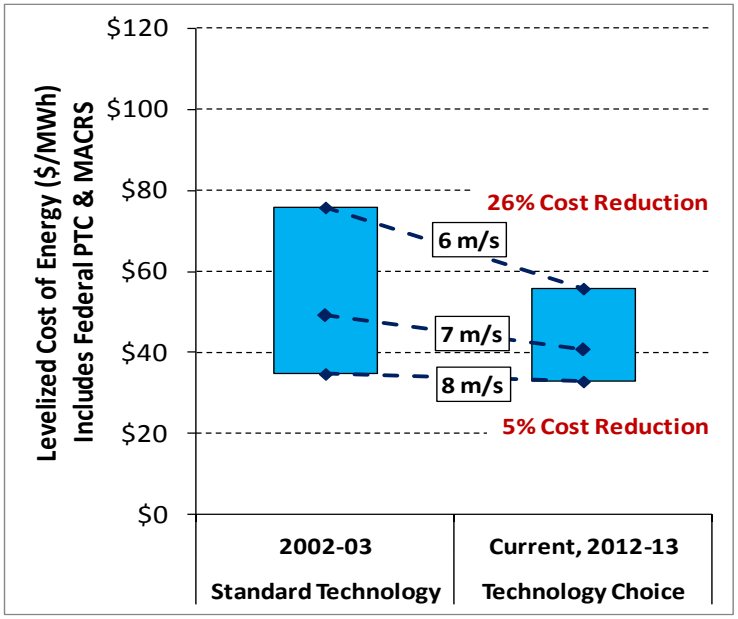
(examples)

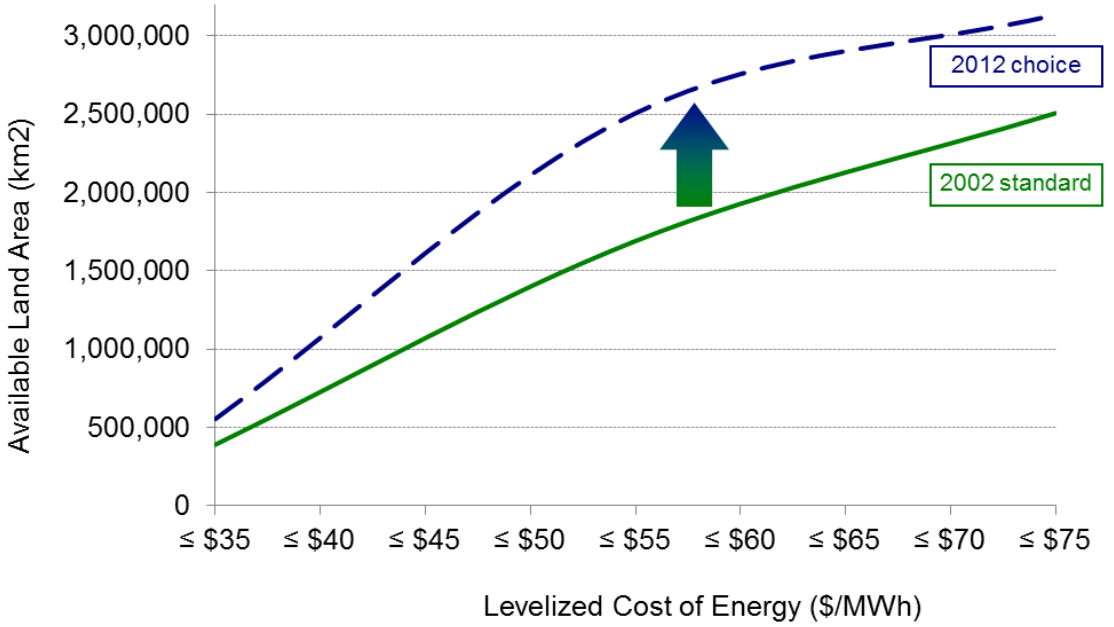
In addition to directly meeting the needs of stakeholders via annual reports, LBNL uses the data underlying the annual reports as a foundation for additional rigorous analysis to inform public debate around renewable energy

New Wind Turbine Technology Reducing Cost in Low Wind-Speed Sites

U.S. Wind Power Projects

(with federal tax incentives – PTC & MACRS; modeled data)

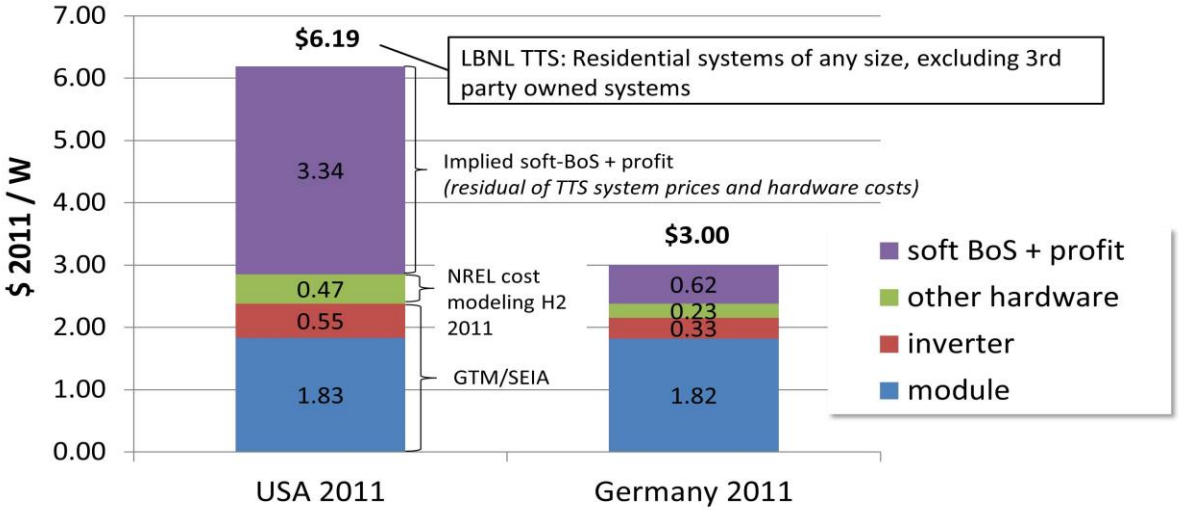




Sources: Wiser et al. 2012; Lantz et al. IEA Report. 2013.

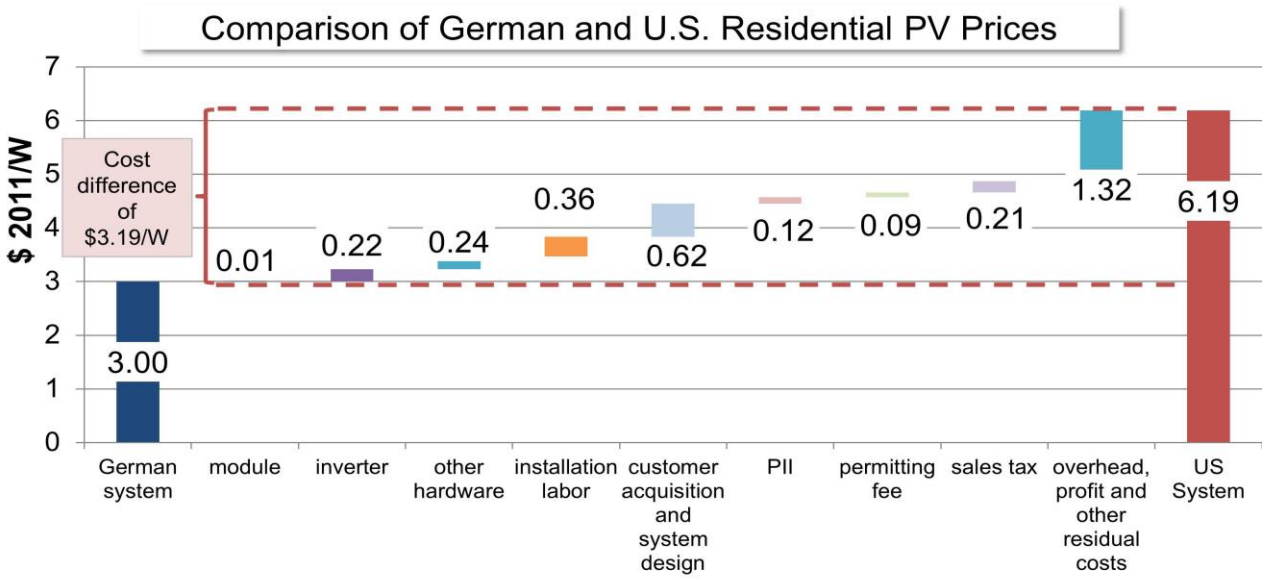
Note: Graphics only include changes in capital cost and turbine design (i.e., capacity factors); graphics do not include changes in O&M, availability, financing, etc.

Germany Demonstrates the Potential for Dramatically Lower PV Costs (vs. U.S.)



Builds on LBNL & NREL collection of data on U.S. residential PV costs, supplemented with surveys of German (and US) PV installers

Illustrates potential for substantial soft-cost reduction in U.S. if German framework conditions can be approached



Source: Seel et al. *Energy Policy*. 2014.

Innovative Deep-Dive Research and Academic Partners Program

Partnering with academic researchers to pursue innovative research projects that exploit the extensive data collected for *Tracking the Sun*, applying econometric tools

→**Academic Partners**: K. Gillingham (Yale), G. Nemet (Univ. Wisconsin), V. Rai (UT Austin)

FY13: Analysis of the impact of local permitting on PV prices and development times

FY14: Developed econometric models to quantify drivers for variations in installed prices across projects and states: (1) general analysis, (2) incentive pass-through, (3) impact of local regulatory conditions and permitting

FY15: Identify and analyze attributes and conditions for low-price systems and drivers for price spread

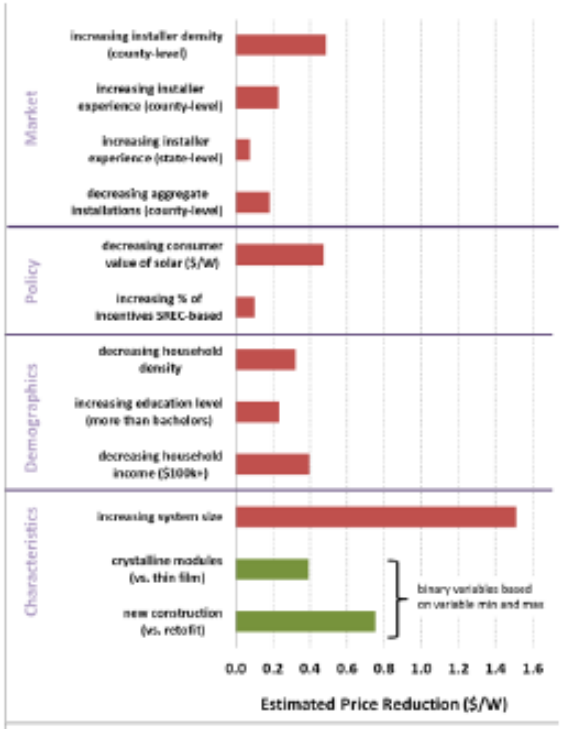


Figure 1. Impact of Various Drivers in Reducing PV Prices

Sources: Dong and Wiser. *Energy Policy*. 2013. Bukhardt et al. *Energy Policy*. 2015. Gillingham et al. LBNL Report. 2014. Dong et al. LBNL Report. 2014.

Expert Elicitation: Wind Technology Advancement and Cost Reduction

IEA Wind Task 26 online survey of wind energy experts planned for 2015; goal is to explore expert views on:

- level of possible wind technology advancement and cost reduction in the near- and long-term
- areas within which advancements and cost reductions are potentially most sizable
- broad drivers most likely to facilitate wind technology advancements and cost reductions

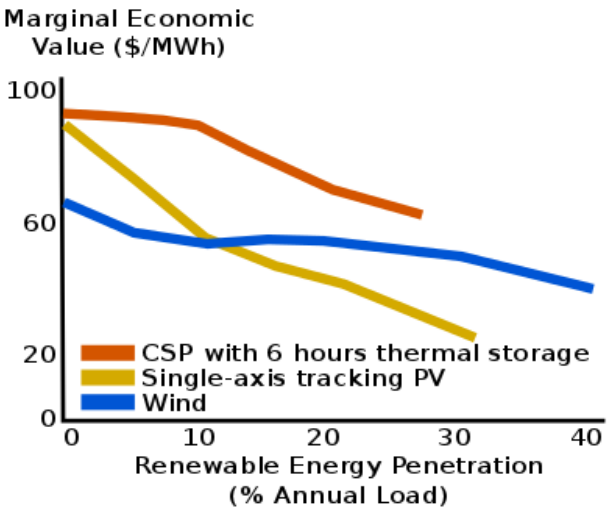
Compare insights for land-based, fixed-bottom offshore and floating offshore wind, and compare views among: a) European & U.S. responses; b) industry & public sector R&D responses; c) survey responses to broader literature review

Variety of Other Selected Topical Analyses *(examples)*

Meeting the targeted needs of utility stakeholders, renewable energy firms, and local-to-international policymakers with rigorous, objective analysis

Renewable Energy Valuation and Integration: Grid Impacts

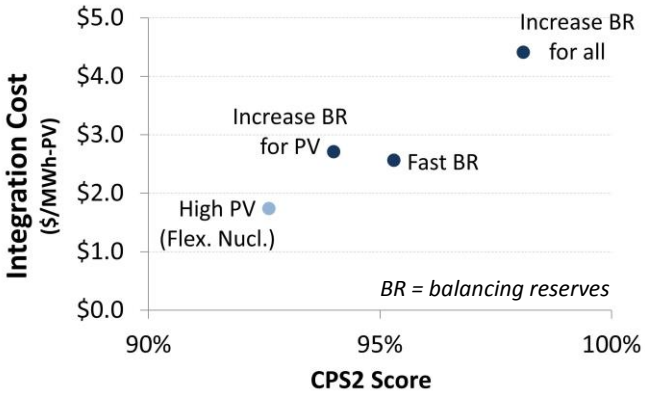
The incremental market value of variable generation changes with penetration. Changes are primarily driven by **energy** and **capacity** value…



… A variety of tools to **increase system flexibility** can be used to partially stem the decline in market value with penetration.

Mitigation measure	Wind penetration		
($/MWh)	20%	30%	40%
Geographic Diversity	2.5	4.9	10.6
Real-time pricing	3.7	5.0	7.9
Low-cost storage	-0.1	0.4	4.4
Quick-start CCGT	0.3	0.3	-0.6
10% PV	1.1	-1.1	-5.2
10% CSP_6	-0.2	-0.6	-4.4

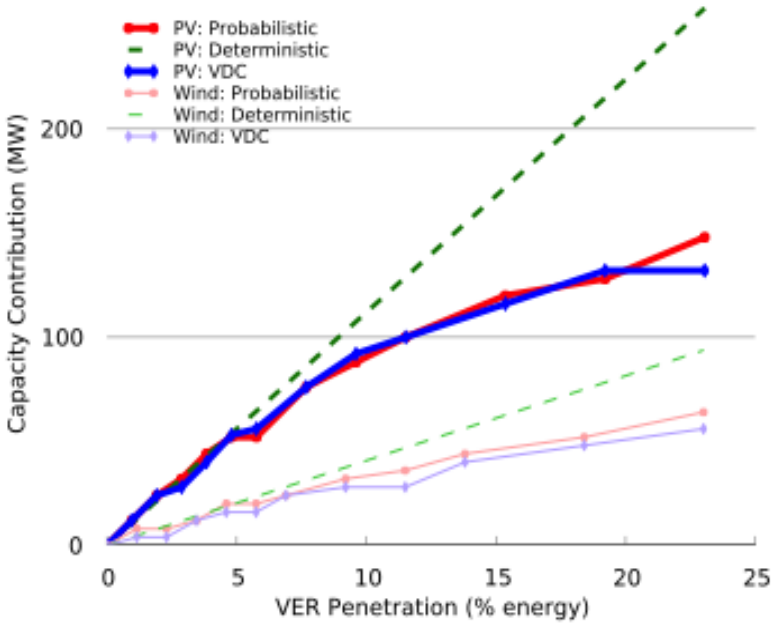
Short-term variability of solar (and wind) is **not** the primary economic concern at increasing renewable penetrations.



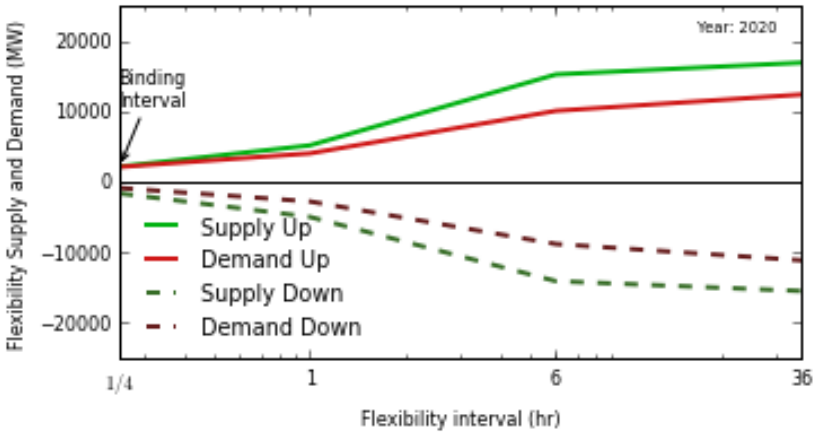
Sources: Mills and Wiser. LBNL Report. 2012.; Mills and Wiser. LBNL Report. 2014.; Mills et al. ANL Report. 2013. Also, Mills and Wiser. *IEEE Journal of Photovoltaics.* 2013.; Mills and Wiser. *Wind Energy*. 2013. Jing et al. *Energy.* 2015

Planning for Renewables: Capacity Value and Flexibility

Full reliability simulations are challenging in capacity expansion models, leading to approximation methods; Sandia/LBNL developed an approach that performs similar to the reliability approach, even at high RE penetrations, without significant computational burden



Flexibility Inventory for Western Resource Planners will demonstrate a simplified approach to estimating flexibility supply and demand, applied to IRP resources in LBNL's Resource Planning Portal



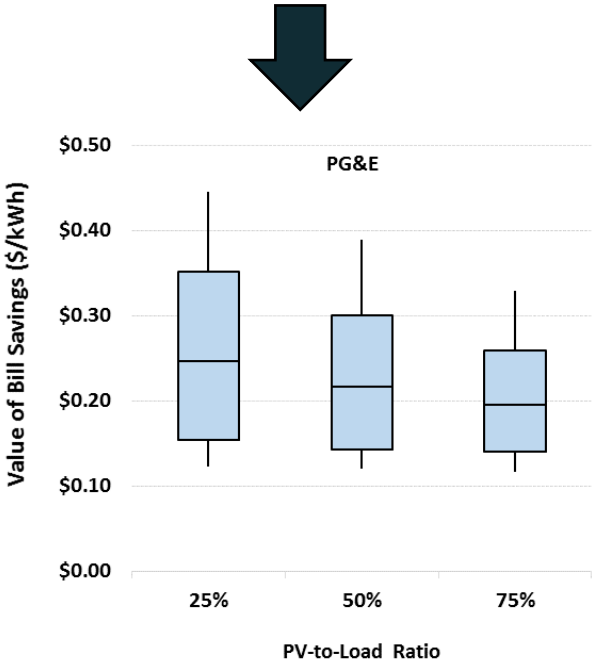
Sources: Munoz and Mills. Submitted to *IEEE Sustainable Energy.*; Mills and Seel. Forthcoming LBNL Report.

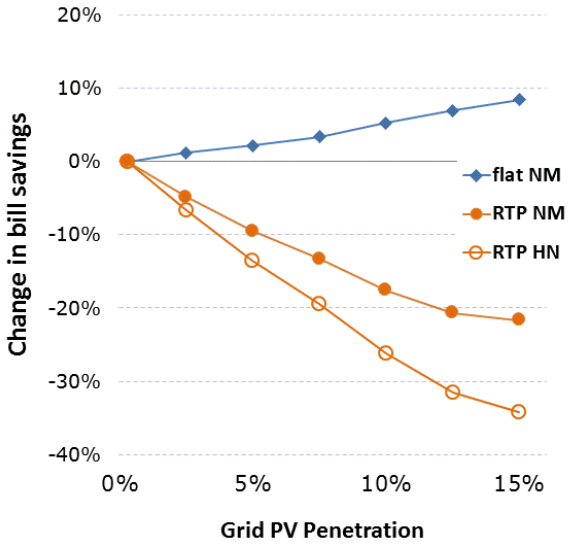
Rate Design Impacts on the Economics & Deployment of Customer-Sited Solar

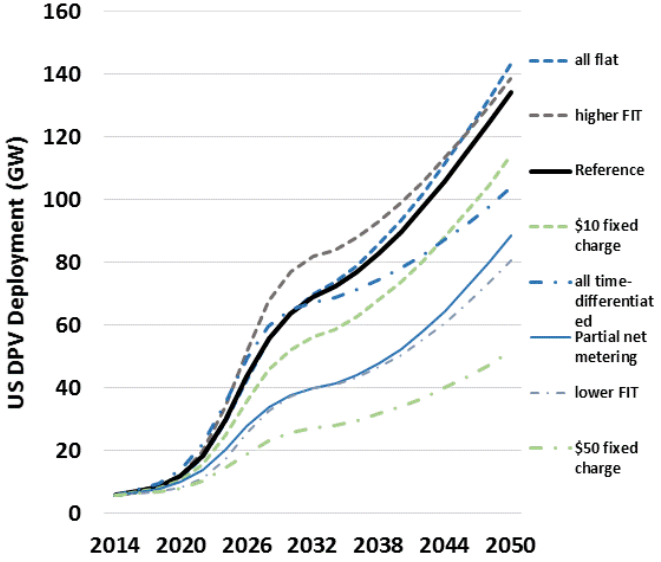
Retail rate design and net metering policies dramatically impact the customer-economics of residential & commercial PV systems.

As **PV penetrations increase**, and under other future conditions, retail rates will change, causing further changes to the customer-economics of PV.

Retail rate design and net metering policies also impact future residential and commercial PV deployment levels.







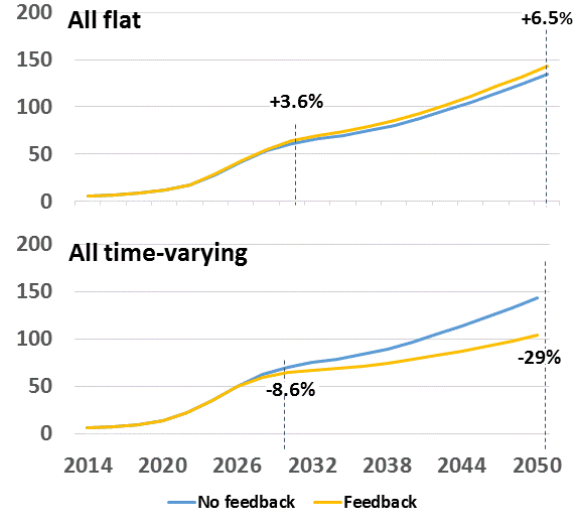
Sources: Darghouth et al. *Energy Policy*. 2011.; Darghouth et al. *Energy Policy*. 2014.; Mills et al. *Energy Policy*. 2008; Darghouth et al. 2015 (forthcoming)

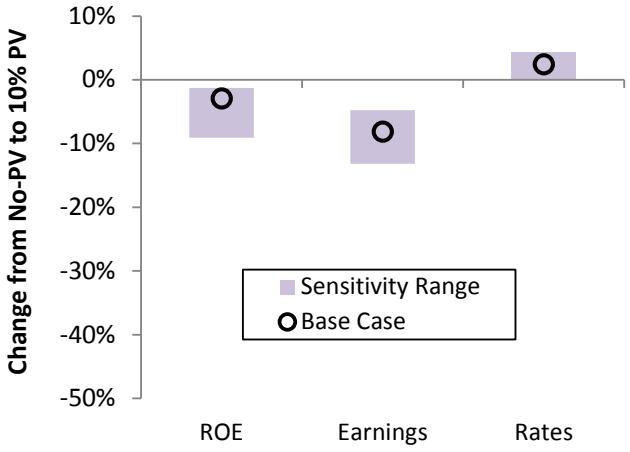
Impact of DG PV on the Traditional Utility Business Model

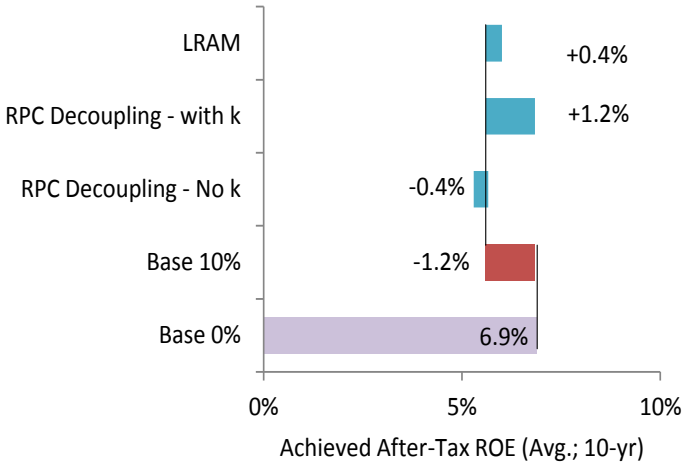
Increased DG PV leads to feedbacks in customer economics that either accelerate or decelerate PV deployment depending on rate design.

Increased DG PV can impact **utility profitability and rates**, though the magnitude of impact depends on utility circumstances.

Increased DG PV can impact **utility profitability and rates**, though multiple approaches exist to mitigate those impacts.







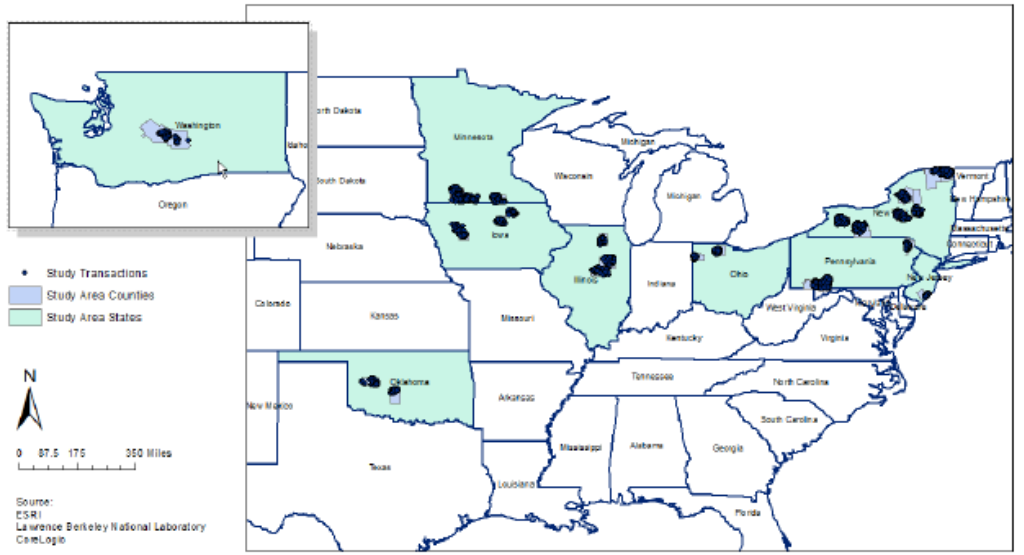
Sources: Satchwell et al. LBNL Report. 2014; Darghouth et al. LBNL Report. 2015 (forthcoming).

Impact of Wind Projects on Residential Property Values

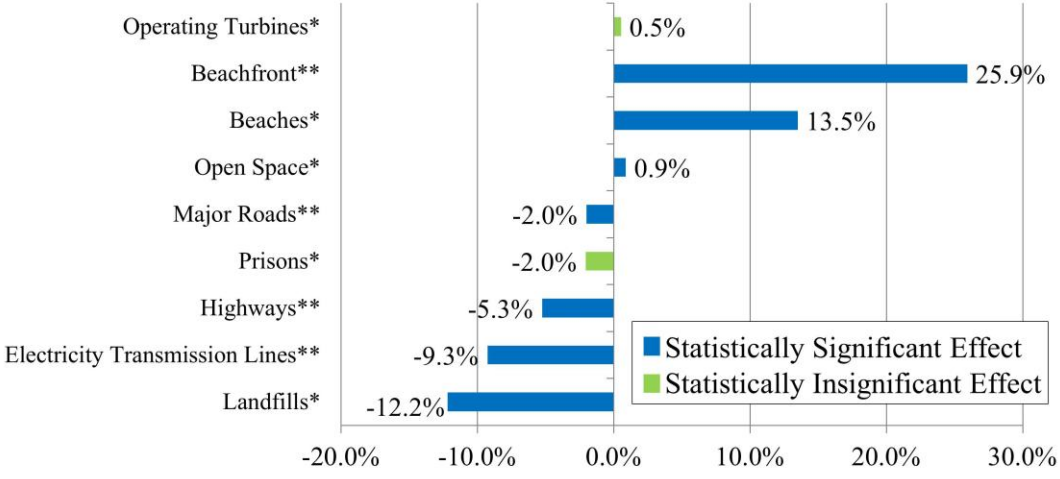
Based on a nation-wide sample (see sample on right) and on a Massachusetts sample (see results on right)…

No statistical evidence that property values of homes located in proximity to turbines have been <u>systematically</u> affected by wind projects

Figure 1: Map of Transactions, States, and Counties



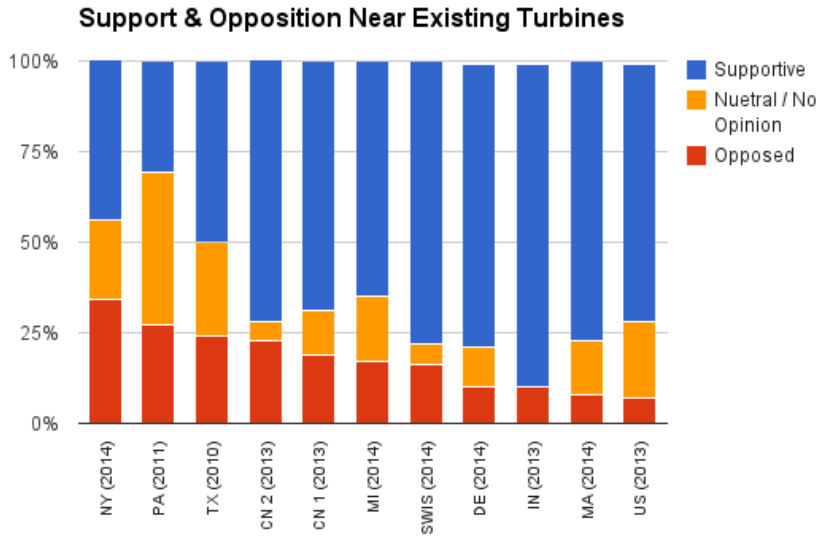
Massachusettes Home Price Impacts



Sources: Hoen et al. LBNL Report. 2013..; Hoen et al. LBNL Report. 2014. Hoen et al. *Journal of Real Estate Research.* 2011.

Baseline Survey Of Residents Near Large Scale Wind Installations

Although a number of US studies have found high levels of support near turbines (see figure), none are transferable to the full population of residents



Other questions also remain:

- Levels of stress and annoyance near turbines?
- Drivers for support or opposition?
- Comparative impacts to other energy/infrastructure sources?
- Changes over time as people move into area?

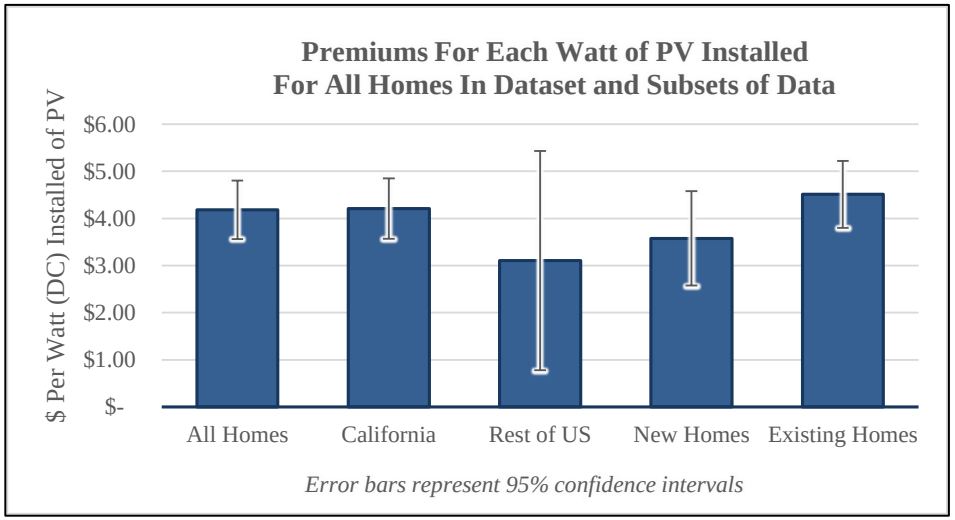
Current 2015-2017 effort will survey large numbers of individuals near turbines to examine these questions and provide baseline understanding of impacts to the population

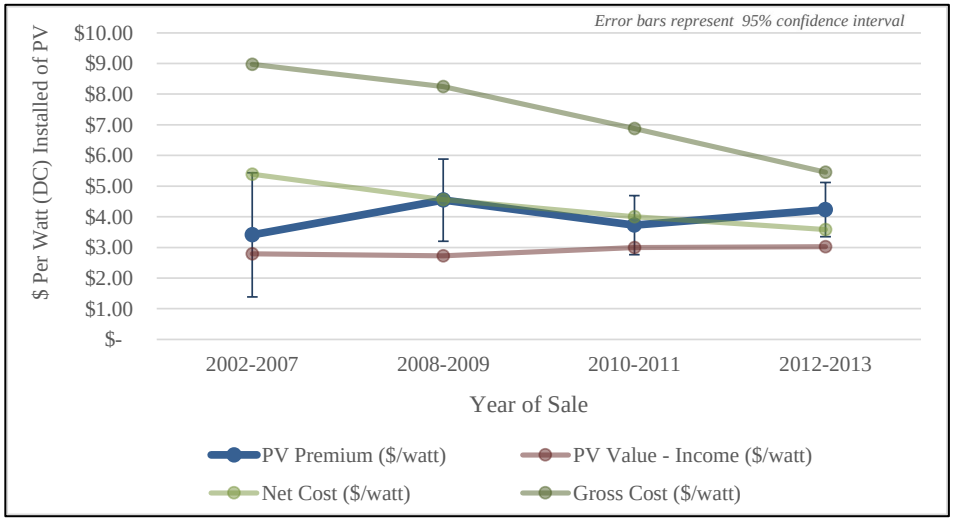
Analyses of Value of Residential Properties With Photovoltaics

Eight state sample of PV homes produced strong evidence of a premium, across all data subsets (top figure)

Premiums stable over time despite falling gross costs of solar (bottom); premiums similar to predicted using income or net costs (bottom)

Future work hopefully to analyze TPO sales



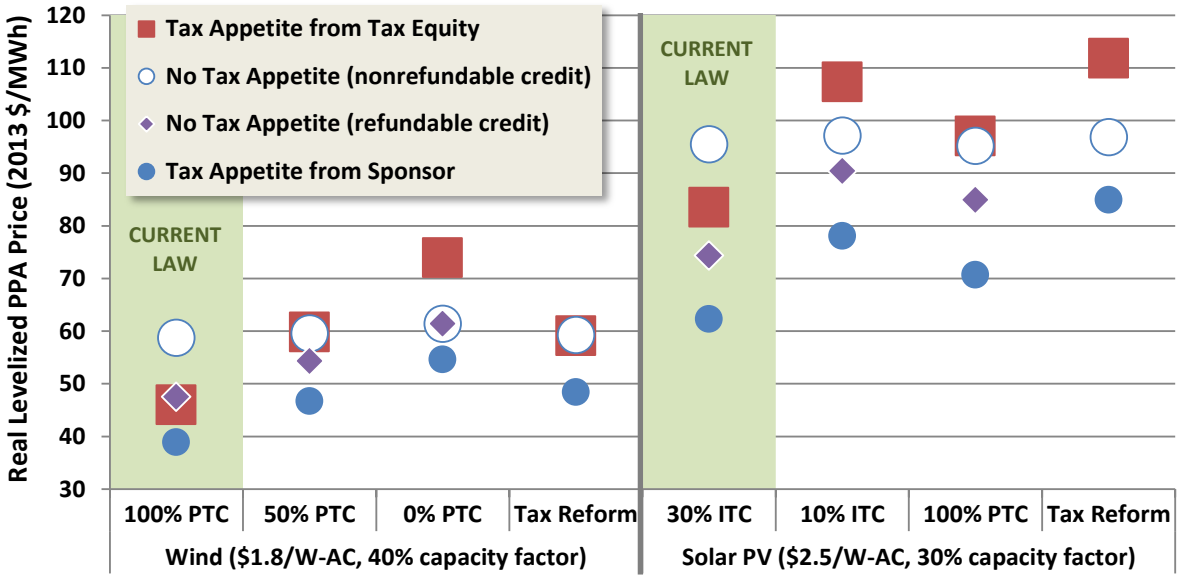


Sources: Hoen et al. LBNL Report. 2011.; Hoen et al. LBNL Report. 2013.; Hoen et al. *Contemporary Economic Policy*. 2013.; Hoen et al. LBNL Report. 2014.

Wind/Solar Finance Work

Explores the impact of policy on project finance and LCOE

2014 work finds that third-party tax equity is likely to be displaced by debt (or other cheap capital, like yieldco equity) under most future scenarios in which ITC/PTC are phased down/out.



2015 work estimates the incremental federal tax benefits provided to TPO (vs. host-owned) residential PV, and explores how states can level the playing field were that desired.

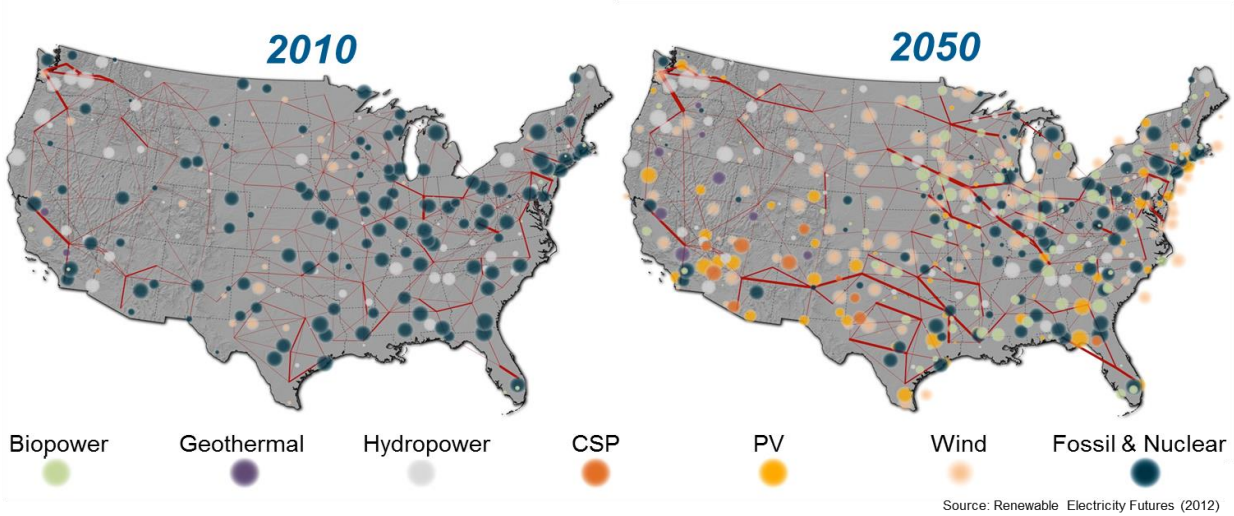
Calculation of Incremental 30% ITC/Grant Provided to TPO Systems

	Median TPO (FMV)	Median Host-Owned (Installed Price)	Difference (TPO - Host-Owned)	Incremental ITC/Grant	
				30% of Difference	Applied to a 5 kW_{DC} system
	2013 $/$W_{DC}$	2013 $/$W_{DC}$	2013 $/$W_{DC}$	2013 $/$W_{DC}$	2013 $
2009	11.7	8.4	3.3	1.0	4,950
2010	9.0	7.2	1.8	0.5	2,700
2011	8.2	6.5	1.7	0.5	2,550
2012	*7.0**	5.4	1.6	0.5	2,400
2013	*6.0**	4.7	1.3	0.4	1,950

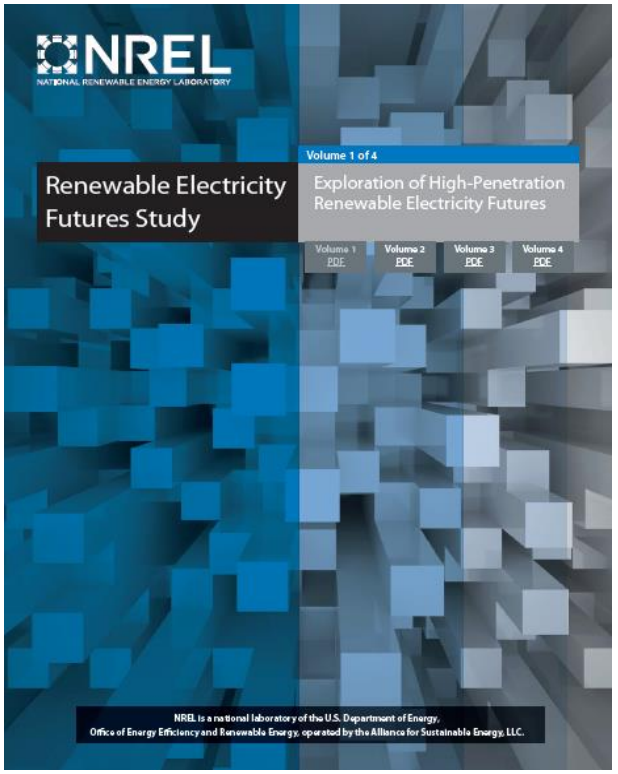
* TPO FMV and host-owned installed price data come from the *Tracking the Sun VII* (Barbose et al. 2014) data shown in Figure 1, except for in 2012 and 2013, when the TPO FMV is set to match Treasury guidance of $7/$W_{DC}$ and $6/$W_{DC}$, respectively (for reasons explained in the text).

Sources: Bolinger. LBNL Report. 2014. Bolinger. LBNL Report. 2015.

RE Futures: An Analysis of an 80% U.S. Renewable Electricity Future



Source: Renewable Electricity Futures (2012)



Other multi-party studies include: 20% Wind Energy Report (2008), Wind Vision (2014), SunShot Vision (2011, 2015), Hydropower Vision (2015); IPCC SRREN (2011), IPCC AR5 (2014)

Also published in IEEE, Applied Energy, etc.

Understanding the Benefits and Impacts of Renewable Energy

LBNL (and NREL) has developed methods to assess in physical and, where feasible, monetary terms the "secondary" benefits/impacts of renewable energy.

First applied in Wind Vision; now being applied in Hydropower and Sunshot Vision studies and also to assess state-level RPS policies.

- Greenhouse gas emissions reduction
- Air pollution impacts
- Water use reduction
- Energy diversity and risk reduction
- Workforce and economic development impacts

Direct State and Federal Policy Assistance

State and Federal RE Policy Assistance

- LBNL conducts technical analysis & advises states and the federal government on renewable energy program design → typically linked to our research, as presented earlier
- Areas include: RPS, net metering/rate design, utility business models, RE valuation / integration, tax policy, financing & financial incentives, etc.
- Examples:
  - Kentucky value of solar energy
  - Arkansas RPS/CES scoping
  - Nevada PV-DG net metering C/B analysis
  - NPCC utility resource planning
- Regularly brief policy-makers on our work: e.g., NGA, NCSL, NARUC, CESA

Sources: Bolinger et al. *Energy Policy*. 2010.; Darghouth et al. *Energy Policy*. 2011. ; Wiser et al. *Energy Policy*. 2011

Conclusions

The Value of and Audiences for Our Work Are Multifaceted

- Diverse product types
  - Direct assistance to policymakers, on request
  - Foundational data collection and dissemination
  - Rigorous analysis of underlying data
  - Other selected research efforts where a need exists
- Diverse audiences: from international climate negotiators to local permitting authorities, and from utility managers and renewable energy stakeholders to academics
- Three over-riding goals
  - Stay nimble to be responsive to emerging issues
  - Maintain a mix of “foundational” and “intellectual” work
  - Emphasize rigor, objectivity, and independence

Thank you for your attention.

Questions?

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